[De]partment of Agriculture Agricultural Research Service February 1992

Agricultural Research

Farming Problems?
Guidance From Outer Space
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Tending the Fields From Afar

Here's a pipe dream for you: At the push of a button, faraway fields report in on the status of their soil, water, and crops. Instantly, farmers are able to take action against insect pests, weather changes, or deteriorating soil conditions.

Currently, the concept of long-distance monitoring—scientists call it "remote sensing"—promises more than it can effectively deliver, in part because of the heavy investment required for the high technology equipment. And often the result is a mountain of data needing interpretation before it can be used in making day-to-day farming decisions.

But now ARS scientists have some down-to-earth, remote-sensing solutions to a number of these problems. In this issue, an article describes how tractor-mounted computers may use Global Positioning System (GPS) satellites to help farmers save fertilizer, cut water pollution risks, or measure encroaching salinity in crop fields.

Some remote-sensing systems do not require orbiting satellites. In February 1991, Agricultural Research told of airplanes equipped with special video cameras that bring back to research labs a videotaped bird's-eye view of the relative health of crops still growing in the fields. The same system is also used to provide information on the effectiveness of various irrigation management systems.

One camera uses a near-infrared filter, one uses a red filter, and the third is equipped with a yellow-green filter. The three images feed into three Super-VHS recorders, and a fourth recorder captures the color-infrared composite.

The scientists can tell whether the crops they're seeing on tape are healthy or plagued by pests, environmental stress, or disease—information that farmers can use in limiting the damage.

An important side benefit for farmers: Such aerial videos could speed up the process of settling crop insurance claims after a disaster. As an alternative to waiting for an adjustor to finish trudging the fields, video offers a quick photographic document of the location and size of damaged areas.

Other potential benefits of an "eye in the sky" include early information on:

- Range regrowth, a prime consideration in calculating stocking rates for livestock.
- Damage from herbicides drifting from nearby crops.
- Changes in the vegetative lineup on the range due to weather or grazing patterns.
- Nutrient deficiencies in crop and range plants.

Such monitoring can help reveal what happens to rain once it's fallen: How much moves downward through the soil, how much drains away, how much is taken up by thirsty plants.

Another very interested audience includes those whose livelihood depends on the latest news on the status of the nation's ranges, pastures, and croplands.

Someday, scientists say, farmers and ranchers may be able to pop a tape into their home VCR to check on the health of their crops, whether the potential problem is an encroaching insect, an invasion of weeds, or simply lack of rain.

Remote sensing's benefits aren't limited to farmers. The same three-camera system developed by the ARS researchers to monitor crop health might someday go into space with NASA craft. There it might be used for purposes like checkups of marine environments such as Texas' South Padre Island, where oyster beds are threatened by urban pollution.

Turning to another area of concern, when scientists wanted a closer look at what happens to heavy rains hitting the range at Walnut Gulch near Tombstone, Arizona, in the summer of 1990, they tackled the problem with equipment ranging from rain gauges to airplanes and satellites. [See *Agricultural Research,* November 1990]

While researchers on the ground measured rainfall, runoff, water movement into and through the soil, soil moisture levels, evaporation, water uptake by plants and other factors, remote-sensing equipment on the airplanes and satellites spewed out similar data from on high.

One early finding from the Arizona effort: Soil moisture levels after heavy rains tend to be more uniform over larger areas than was previously thought. Researchers say this sort of information could have an impact on the use of remote sensing in flood prediction.

Improvements in drought prediction could also be a possibility. It appears that "sensible" heat from the land—the kind of heat you can feel—as well as "latent" heat, energy stored in the form of evaporating water, play a major role in determining when and where rain will fall.

If this proves true, reliable remote-sensing data on the water and energy balances of semiarid rangelands could play a role in anticipating changes in climate on a regional or even a global scale, scientists say. In turn, scientists must learn how to monitor more accurately the hydrologic cycle of the rangelands.

Fine-tuning applications of crop inputs such as fertilizer means less is wasted—a savings to the farmer. And tightening the margin between what's applied and what's needed by the crop is also good news for the environment, since the likelihood of problems such as surplus fertilizer leaching into groundwater supplies is lessened.

The heyday of technological advances for U.S. agriculture is far from finished. Someday farmers may count among their most valuable "farm tools" a satellite they've never seen, but that faithfully beams down the information they need to play their part in feeding the world.

Sandy Miller Hays
ARS Information Staff

Agricultural Research

Cover: ARS soil scientist Jim Rhoades inspects severely salt-damaged farmland in California's San Joaquin Valley.
Photo by Scott Bauer. (K-4486-19)

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Vol. 40, No. 2
February 1992

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Agricultural Research is published monthly by the Agricultural Research Service, U.S. Department of Agriculture, Washington, DC 20250-2350.
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Subscription requests should be placed with New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. Please see back cover for order form.

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Satellites Key to New Farming Aids

Fertilizer, seeding rates, even salinity measurements are guided by computers linked to a space-based global positioning system.

NASA

High above the Earth hovers a fleet of satellites that enables all sorts of minor miracles to take place on the planet below.

Developed by the Department of Defense, the Global Positioning System (GPS) proved itself a lifesaver when deployed for maritime rescue operations and during Operation Desert Storm.

But don't think the military has clamped a veil of secrecy on GPS. Quite the contrary; the technology has been transferred and adapted to the purposes of surveyors, geologists, and even to suit the needs of the fishing industry, where it pinpoints the best oceanic fishing areas. And as any saltwater fisherman can tell you, getting to within a 100 feet of any spot in the open ocean is a pretty good feat.

The GPS has stirred up a flurry of interest among agricultural researchers. At ARS' Soil Tilth Laboratory in Ames, Iowa, agricultural engineer Tom Colvin is busily perfecting a GPS-linked system called JANUS to take the guesswork out of fertilizing fields. His aim: to cut costs and reduce harm to the environment. Meanwhile, ARS scientists in California who are concerned with soil salinity are also gazing hopefully at the heavens.

Just a Spoonful of Chemicals

"Why treat an entire field with the same amount of chemicals?" Colvin asks.

His answer is JANUS, a means "to portion out chemicals" via calculations from computers and the government satellites already in space.

JANUS stands for Joint Agricultural Navigation Using Satellites.

"JANUS uses what we know about the field's past to guide us in its future management," he says. "We use a dossier of data collected on crop yields and soil conditions to map each part of a farm field. Then GPS accurately pinpoints where the tractor or combine is tracking."

Such precision can give farmers on-the-spot data so they can quickly decide on how much animal waste, chemicals, and seed to apply and just where to use them.

"A farmer in a field can identify the exact spot—give or take 20 feet—as the tractor passes over and can adjust the amounts of fertilizers, herbicides, pesticides, or manure accordingly. The farmer can even alter the number of seeds planted based on soil fertility," Colvin says.

Farmers have known for a long time that over large acreages the soil can vary greatly. While one area can produce up to 180 bushels of corn, another will yield just 60. Yet farmers generally apply chemicals uniformly to

The Global Positioning System (GPS) comprises 16 radio-equipped navigational satellites, each circling the Earth in its own 12-hour orbit, plus terrestrial computers that receive and process down-linked information. When complete, the system will have 24 satellites, including 3 in-orbit spares. An onboard atomic clock enables each satellite to continuously broadcast a signal that indicates the spacecraft's exact position. Ground-based receivers use simultaneous readings from three satellites to perform precise triangulation, exactly identifying any location on Earth.

SCOTT BAUER

Precise application of fertilizers or other chemicals is possible using the experimental global positioning unit being installed by engineering technician Jeff Cook. (K-4527-17)

SCOTT BAUER

Research assistant Jack Ambuel monitors global positioning satellites with mobile receiver system. (K-4527-15)

sustain yields at the highest level. Such excessive use wastes money and can cause residues to build up and contaminate water supplies.

For the last 3 years, ARS researchers at the Ames lab have accurately measured the yields of soybeans, corn, oats, and alfalfa on a 160-acre area that was selected for this study. Data were collected on a laundry list of other variables—soil fertility, moisture, and temperature, weather factors, soil profiles, soil tilth, and organic matter. Crop yields were measured with combines every 40 feet.

All these data are stored in a computer database at the Ames lab called Geographical Information System, or GIS. The GIS is used to combine and integrate information on past yields, current soil fertility, and current and past weed and other pest infestations as well as other data for each acre of a 40-square-acre field.

Based on data collected from each sector, JANUS will help farmers in making actual microsite decisions regarding all field applications sector by sector.

How JANUS works is simple. Two satellite radio receivers—one tractor-mounted, the other at a fixed spot outside the field—pick up signals generated at regular intervals by Earth-orbiting transmitters.

Then, based on the signals received from GPS by the two radios, a computer on board the tractor pinpoints the longitude and latitude of the tractor's position on the field to within about a 10- to 15-foot accuracy.

Within the next 5 years, Colvin says, JANUS' accuracy could be measured in inches.

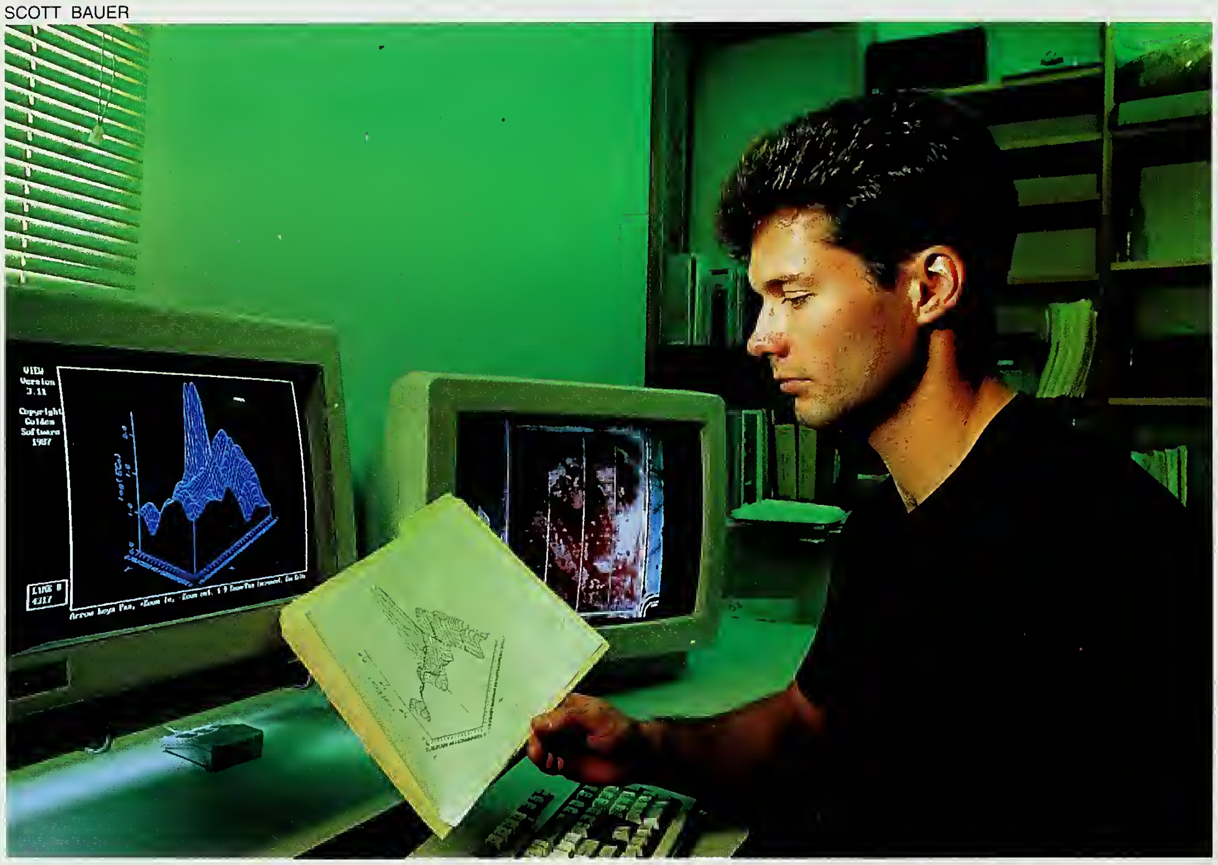
Once the data on positioning is collected, it is automatically correlated with other information from the computer on that sector's soil history.

Last year, the system with two receivers cost about $50,000. There's also an additional expense for tractor-mounted equipment to enable farmers to vary the application rates of whatever they are applying. That gear is already available and is not as costly, he says.

"In 5 years, as the number of users of the technology increases, JANUS should cost $10,000 or less," Colvin says. "Some state-of-the-art tractors already have the electronics capability of monitoring just what the tractor is doing—like keeping track of slippage so farmers know whether they're wasting fuel," he says. "Some farmers already use 2-way radios, so very little is needed for a complete system except a satellite receiver and a computer."

The lab's system has been in operation for less than a year. "It has worked well on several different vehicles, including a pickup truck and a four-wheel-drive tractor," he says.

SCOTT BAUER



Statistician Scott Lesch compares the field data of crops affected by high salinity with aerial infrared images of the crops. (K-4489-2)

Colvin has had inquiries from farmers with large farms in Indiana, Illinois, and Iowa who have expressed interest in trying JANUS on their fields. If farmers find it too costly, "they could either rent equipment or hire crews from a cooperative," he says. Colvin also envisions using JANUS to guide farmers in making other important decisions like planting, scouting for pests, and harvesting crops.

"Eventually, JANUS should take much of the guesswork, except for weather variables, out of farming. With so much information available on each part of the farm, farmers will be pretty darn sure that any decision concerning their fields is the best possible," he says.

The JANUS technology may be a boon for environmental researchers, he says. Two areas on adjacent farms in central Iowa are currently being studied to compare conventional with alternative or sustainable farming practices. [See *Agricultural Research,* October 1989, pp. 4-7.]

"We'll be able to pinpoint how the two management systems affect the ecosystem of each area by being able to easily return to a specific site," Colvin says.

"The greatest benefits from JANUS," Colvin says, "will be reaped by farmers who practice sustainable agriculture and desperately need this information. It will allow them to use less chemicals, disturb the soil less, and better protect groundwater while getting the greatest yields possible."

On-the-Go Salinity Measurements

One specific problem that seems tailormade for GPS investigation is that of soil salinity. The widespread degradation of some of Earth's most productive agricultural lands can be curbed if salt buildup is slowed or halted.

"If we can locate areas where excessive salinity is developing, we can undertake practices that will control it in most cases," says ARS soil scientist James D. Rhoades.

Salts accumulate in soil as the result of irrigation, because all waters contain some dissolved salts. When crops take up water, they leave the salts such as sodium and calcium chloride and sulfate behind in the soil. After a while, soil salts reduce crop yields.

Salinity is often hard to spot. Yields from crops like corn and alfalfa can drop by 25 percent before plants begin to show any visible symptoms, by which time the cost of reclaiming the soil may exceed the land's value.

"To control this vast problem, we first need to obtain accurate, detailed data from large areas," says Rhoades, director of the U.S. Salinity Laboratory, Riverside, California. "Then we can diagnose, manage, and monitor salinity conditions."

Two recently developed mobile systems can rapidly measure soil

RENE DAVIS

Infrared imagery is also used to detect crop-damaging salinity. The white, or sparse vegetation, areas correspond with salt buildup in the soil.

salinity, coupled as they are to the GPS. They instantaneously acquire information on the precise location of each salinity measurement.

This information is collected automatically in the field and stored in data loggers. Thousands of these salinity measurements are made hourly to thoroughly characterize whole fields in a matter of a few hours. Later in a laboratory, computer techniques will process these data and produce maps.

"The new mobile instruments should drastically increase the accuracy and speed of salinity mapping while simultaneously cutting the cost. Using conventional sampling and analyses, time, and labor to collect these samples has been substantial—at least 10 minutes per site. A typical soil sample costs $25 to analyze in a laboratory, and it takes weeks for results to come back. And hundreds may be needed for each 640-acre field. Our devices should be able to measure a field this size in 2 hours at a fraction of the cost," says Rhoades.

Rhoades developed these instrumental techniques, and with help from ARS engineer Lyle M. Carter at Shafter, California, they adapted them into mobile systems.

One instrument is a tractor-mounted, four-electrode sensor system that measures and logs soil electrical conductivity on the go, along with the measurement's location.

The instrument sends an electrical current from one probe through the soil to the other probe. A meter indicates how much resistance the current encounters. The less the resistance, the greater the salt content. Computer techniques then calculate salinity and produce maps and plot cross-section profiles of the field.

the tractor moves at speeds of 3 to 6 miles per hour.

The other instrument is an electromagnetic induction salinity sensor mounted on a spot-spray vehicle that resembles a small, high-clearance tractor. With this remote device, a generator produces an electromagnetic field that penetrates the soil.

This invisible electromagnetic field causes an electric current flow within the soil that is proportional to the soil's

SCOTT BAUER

Extensive salinity damage is apparent in this abandoned cropland in California's Coachella Valley. (K-4481-8)

The four probes are mounted on a 16-foot long, hydraulically controlled tool bar attached to the three-point hitch of a small farm tractor. As the driver steers the tractor across the field, the probes are dragged 4 to 6 inches deep through the soil. Readings are made automatically every second as

salinity. In turn, this creates a secondary electromagnetic field that arises above ground where it is measured and converted to units of soil electrical conductivity and, after computer processing, to soil salinity.

The electromagnetic sensor is mounted on an 8-foot-long boom that

SCOTT BAUER

Using the global positioning satellites and a tractor-mounted salinity sensing unit, technician Robert LeMert (on tractor) and statistician Scott Lesch prepare a computerized salinity map of this field. (K-4492-8)

is attached to the vehicle's front. Hydraulic controls raise and lower the boom to different heights above the ground. Other controls rotate the electromagnetic coils from vertical to horizontal positions. These changes in configuration are made to gather information on salinity within different depths of the soil.

The unit is operated on the go at a single height and coil configuration for salinity measurement at a single depth. If measurements are needed for subsoils at various depths of 0 to 1 foot, 1 to 2 feet, 2 to 3 feet, or 3 to 4 feet, for example, the unit is operated in a stop-and-go fashion. Each stop requires about 30 seconds for the operator to make readings as he or she positions the boom and sensors at two heights and two configurations.

Both measuring systems also contain an antenna, receiver, data logger, and power supply to collect satellite signals that can be decoded to provide location information.

"This will not only help us to map salinity but allow us to acquire information on salinity concentrations at many depths," says Rhoades. Such data helps reveal the extent of leaching (amount of irrigation water that passes below plant roots), adequacy of drainage, and cause of salinity in the region. Then, he says, "we can recommend more appropriate changes in irrigation and drainage practices."

"In one preliminary experiment, we were able to determine how effectively the buried drainage tiles were keeping salinity under control. It was dramatic how accurately our readings correlated with tile location," Rhoades says.

"The mobilized sensing systems also have potential for coping with salinity," says Carter. "If such computerized sensors and controls were on farm equipment, they could interpret data being collected and alter planting and fertilization rates while the equipment is passing through fields."

"It should be possible to get detailed maps of salt loading from the different regions of large irrigated areas. We would get such maps by incorporating the intensive information on soil salinity, along with other data, including soil type, water table depth, soil permeability, leaching fraction, and groundwater salinity, into a commercially available geographical information system and coupling it with a computer model we developed. The model, called TETrans, for Trace Element Transport, can simulate salt movement in soils by using these location-related databases," says ARS soil scientist Dennis L. Corwin at the Riverside laboratory.

Rhoades hopes new equipment, based on these two prototypes, will become commercially available so it can be used by consultants, government officials, scientists, and individual farmers. Because it's based on satellites positioned around the world, the mobile equipment can be used to study any irrigated region on Earth.

The next technological breakthrough, says Rhoades, will be when the remote electromagnetic system is modified so it can collect salinity readings from low-flying aircraft.

The Riverside scientists are also cooperating with James H. Everitt and co-workers at ARS' Subtropical Agricultural Research Laboratory, Weslaco, Texas, in an attempt to link multispectral video photos taken from planes to the salinity measurements obtained from ground-based, mobile systems. If they succeed in translating various colors and hues to degrees of salinity, the need for ground-based measurements can be reduced.—By **Hank Becker** and **Dennis Senft,** ARS.

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Extra Irrigations Protect Cotton

A researcher in Arizona has hiked cotton yields 25 percent by irrigating four times in July rather than two times as is the current practice. That increase might someday translate into an extra $200 per acre for cotton growers.

Secret to the increase, says an Agricultural Research plant physiologist, is preventing stress during the crop's most critical stage—when plants are producing bolls. Bolls are where cotton fibers develop. The most common stress is lack of adequate water.

"We irrigated our cotton every week with about half the amount normally applied every other week in July. Thus, with almost no extra water, cotton growers have the potential to produce about a half bale [250 pounds] more per acre merely by irrigating more often," says John W. Radin at the Western Cotton Research Laboratory in Phoenix, Arizona.

This yield increase was the result of lots of basic research and detective work into what happens to roots during stress. Cotton plants have a built-in survival mechanism that sometimes thwarts yield increases. If plants are under stress when producing bolls, they shed some fruits in an effort to conserve energy and remain healthy. Cotton plants grown on daily drip irrigation (a "just-in-time" approach to water application) shed the least and maintain the highest yields. Radin studied how roots participate in this life-saving process under different irrigation strategies.

Radin discovered that plants on long irrigation cycles, typical of furrow-irrigated, are really no different than daily-drip irrigated plants until boll formation becomes heavy. Then the furrow-irrigated plants begin to lose the capacity to rapidly absorb water from the soil. This ability returns after the bolls are mature. Drip-irrigated plants sail right through that period with no changes.

JACK DYKINGA

Four irrigations instead of the normal two increased this cotton's yield, says plant physiologist John Radin. (K-4504-1)

That means plants under furrow irrigation may not take up water fast enough to satisfy their needs, even after an irrigation when the soil is good and wet. Radin remembered that some old work showed roots die back during boll loading—especially if the plants become at all stressed for water—and cannot regrow very much after rewatering.

Radin speculated that this might be because most assimilates, or plant foods, are going to the bolls, instead of being distributed around the plant. He thinks that drip irrigation "protects" roots against this die-back process during July. That's why he decided to try increasing the irrigation frequency.

Daily drip irrigation has the potential to boost cotton yields by up to 40 percent, but most growers wouldn't find its high installation and maintenance costs economical on a crop like cotton. Drip is used extensively on high-value commodities such as grapes and oranges and in areas where water is more expensive.

Radin compared cotton grown under three irrigation schemes: flood irrigation of level basins, flood irrigation used twice as often during July, and aboveground drip irrigation used daily.

Growers who use sprinkler irrigation might also benefit from more frequent water applications because they can turn it on just when crops need water.

On the other hand, applying the extra water on sloped, furrow-irrigated cottonfields would be difficult because small, evenly applied amounts of water are difficult to regulate and can lead to wasteful water use. Most cotton growers in the Western United States use the furrow irrigation system.

"I can't say if it will pay cotton growers to switch from furrow irrigation to another irrigation system. I would like economists to analyze the choices. I would also like further investigation of other major crops to see if they too produce more if irrigated at yet-to-be determined critical stages," says Radin.—By **Dennis Senft,** ARS.

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Victims No One Mourns

JOANNE DILDAY

Plant geneticist Robert Dilday checks a rice variety that keeps weeds at bay by releasing a natural chemical. (K-3603-2)

It's enough to put a soap opera to shame: Neighbors killing neighbors, poisoning the environment, boosting a favored few at the expense of others.

But the setting isn't some steamy small town; it's a pastoral meadow or a thriving crop field. And the shocking goings-on aren't a scandal; they're just allelopathy.

That's the term scientists use to describe the ability of certain plants to produce natural chemicals that suppress or even kill other plants. The term was coined more than 50 years ago, in 1937, and researchers are still trying to sort out all the killers—and the victims.

One victim that no one will mourn is ducksalad, the most troublesome aquatic weed in water-seeded rice such as that grown in California and parts of the South.

Happily for rice farmers, researchers with USDA's Agricultural Research Service have found a surprising 347 rice accessions with some natural ability to repel ducksalad—a boon not only for farmers' finances, but also for the environment, since herbicide needs could eventually be reduced.

This discovery began accidentally in the early 1980's, according to Robert H. Dilday, a plant geneticist at the ARS Rice Production and Weed Control Research Unit at Stuttgart, Arkansas.

"In 1983 and '84, I was screening accessions from the world rice germplasm collection for herbicide tolerance," Dilday recalls. "We had a natural infestation of ducksalad in our test plots. I noticed the ducksalad would grow right up to some of the rice plants, but other rice plants didn't have any of the weed around them."

His interest piqued, Dilday obtained funds to begin evaluating rice accessions specifically for allelopathic qualities. In 1988 and 1989, Dilday, fellow ARS researcher Roy J. Smith, Jr., and Palo Nastasi of the University of Arkansas evaluated some 10,000 rice accessions.

From those, the researchers pinpointed 347 with allelopathic activity against ducksalad—about 3.5 percent of the accessions checked.

At that rate, says Dilday, the rice germplasm collection as a whole could contain as many as 500 accessions that could fend off ducksalad to some degree.

In 1988, the first year of the allelopathy evaluations, Dilday also identified 132 rice varieties that repelled redstem, another aquatic weed, and six that looked promising for resistance to broadleaf signalgrass.

And it looks like there are two other weeds that allelopathy may be promising against—rice flatsedge and barnyardgrass.

"We have natural infestations of those two in our rice plots, and we're seeing some activity against them in rice lines from India, the Philippines, and Bangladesh," Dilday says.

In some instances, the rice accessions that repel ducksalad are able to maintain a weed-free area with a radius of up to 10 inches around their base. More typical, though, is a distance of 5 to 6 inches, Dilday says.

Now ARS and university scientists are working to identify the chemistry involved in the allelopathy, Dilday says.

"We're looking at water samples, root samples, and aboveground plant parts," he notes.

"If we can identify the chemicals involved, chemical companies might be able to copy them. I'm also testing to see if the allelopathic substances linger in the soil for more than a year."

Another possibility is breeding the allelopathic characteristic into commercial rice varieties, Dilday adds.

"I have been able to breed it into third-generation plants, so we know the allelopathy is passed to offspring," he says.

Especially heartening is the knowledge that the allelopathic capability exists in a wide variety of rice cultivars—the 347 come from 30 different countries—with a great variety of other characteristics.

"For example, it is found in plants of all three grain types—short, medium, and long; in different plant heights, ranging from semi-dwarf to extremely tall; and in early and late maturing plant types," Dilday points out.

"That diversity tells me it's not genetically linked to specific physical characteristics, and that could make it easier to transfer through breeding into commercial varieties.

"I think allelopathy is just coming into its own as a method of weed control," he continues. "I think down the road we will not have as many herbicides available because of environmental restrictions. So if we don't develop something like this to help control weeds, it could be hard to stay in the rice business."

Weeds That Fight Back

At least a dozen weeds have been identified as having allelopathic abilities of their own.

At the ARS Plant Protection Research Unit in Ithaca, New York, weed scientist Roger D. Hagin found that one of these, quackgrass, leaves behind a substance that kills alfalfa seedlings when the quackgrass itself is killed.

In researching whether the same sort of substances are exuded from living quackgrass, Hagin has identified the substances as 5-hydroxyindoles or their derivatives. These are natural compounds known in only a few other plants, such as *Griffonia,* a legume from West Africa.

One of these, 5-hydroxyindoleacetic acid (5-HIAA), acts as a plant growth hormone, he notes. At the proper levels, it will stimulate plant growth, but too much can kill a plant. Another compound, 5-hydroxytryptophan (5-HTP), acts as a growth inhibitor in quackgrass and some other plants.

A carboline compound derivative of 5-HTP kills garden or field slugs and does not appear to affect plants.

All three compounds are given off by dead quackgrass plants, and their effects can linger in a field for up to a year, Hagin says.

"Generally, the worst is past after 2 months," he adds. "But it will inhibit a lot of weeds; you can get dandelion kill from it."

Hagin says at least one chemical company is contemplating manufacture of a synthetic version of the carboline as a molluscicide. "The other 2 compounds may be adapted as selective weed killers," he adds.

Quackgrass isn't the only plant determined to take something else with it when it goes. A 3-year pasture rejuvenation project in the late 1970's and early 1980's revealed that killed Kentucky bluegrass leaves a hostile setting for at least one legume, birdsfoot trefoil.

Tests indicate the compounds from the grass were similar to those in quackgrass. I've seen it kill dandelions and broadleaf plants, so it has potential as a herbicide, too, just like quackgrass."—By **Sandy Miller Hays,** ARS.

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KEN HAMMOND

Weed scientist Roger Hagin examines various grass varieties with allelopathic characteristics. (K-4389-1)

Rust-No-More Beans

New varieties fend off all 55 known rust-causing fungi.

SCOTT BAUER

Plant pathologist Rennie Stavely (center) and technician Vansie Blount (right) examine a rust-resistant bean variety, while technician Eugene Frazier records their findings. (K-4392-6)

Every summer afternoon, tens of thousands of commuters drive past J. Rennie Stavely's bean garden on their way home for supper.

For many of the commuters, supper will feature a dish of this high-protein, high-fiber food—perhaps refried beans in a Tex-Mex medley...snap beans zapped in the microwave...hearty navy bean soup...a tangy cold salad of green and yellow wax beans and kidney beans...or maybe Aunt Molly's secret six-bean chili.

Soon, Aunt Molly's recipe may use beans from new, up-and-coming varieties being tested in Stavely's 2-acre research plot growing near Interstate 495, the freeway girdling the Nation's Capital.

Those new beans, says Stavely, a plant pathologist with the Agricultural Research Service, will stand up to all 55 identified U.S. strains, or races, of the fungus that causes bean rust.

"Rust is among the worst diseases of bean plants," says Stavely, who is with ARS' Microbiology and Plant Pathology Laboratory in Beltsville, Maryland. "In a bad year, it can cost $250 million in losses nationwide. An epidemic can cut yields by 50 to 80 percent or more."

The rust fungus is *Uromyces appendiculatus.* It robs water and nutrients from leaves and stems, and the plant struggles just to survive.

Rusts, among the most highly evolved fungi in nature, are obligate parasites, meaning they reproduce only on their specific host plant, in this case the bean plant.

"Rust rarely kills a bean plant—that would destroy the fungus' only source of reproductive energy," says Stavely.

The fungus produces five kinds of spores at different stages in its annual cycle. Plants become infected with wind-carried white spores in spring. These produce more white spores as well as rust-colored spores that give the disease its name.

Both spore types germinate and enter a leaf through stomates—openings through which the plant draws water and carbon dioxide. Germ tubes from spores grow between leaf cells and produce suckers that enter the cells to rob nutrients. Rounded brown pustules form on the leaves, which may die. The plant becomes debilitated and produces fewer pods.

Stavely says the risk of rust is worst in humid climates such as the Southeast, mid-Atlantic, and parts of the Midwest. It's usually not a problem in the arid West.

From 1971 to 1991, severe rust epidemics occurred in 10 states and for at least 5 years in Florida, Maryland, New Jersey, Tennessee, and Virginia. In 1991, epidemics struck dry beans in Colorado and snap beans in Florida.

But Stavely and other scientists around the country are rustproofing *Phaseolus vulgaris,* the common bean plant. That will safeguard this species' uncommon diversity of foods: green snap beans, yellow wax beans, and an assortment of dry beans—navies, pintos, great northerns, and others.

Rustproof beans get their start in thousands of mini-plots—like the 392 at Beltsville, Maryland, in 1991—in a cooperative program of ARS, seven universities, and commercial breeders. Stavely coordinates the program.

There's no real cure for rust, he says. Fungicides can reduce infection, but the most widely used one was recently withdrawn because of environmental concerns.

Now, however, farmers and gardeners can look forward to rust-resistant plants—without resorting to chemicals. That's because nature gave a few

P. vulgaris plants—and related species—the genetic know-how for stopping rust from taking hold, or bowing so slightly to it that there's little or no loss in bean yield or quality.

Stavely and colleagues are putting those genes into breeding lines that commercial breeders are turning into marketing varieties. Since 1984, the scientists have released 53 lines of beans resistant to all 55 rust races.

Like Jack's magic beanstalk, the work has sprouted the new beans at a quickening pace: 17 lines released from 1984 to 1988, 36 lines since then.

Bush-type green snap beans for the fresh market make up a dozen of the lines. Another 30 are green snap or yellow wax beans for processing into frozen or canned products. Seven are navy beans, and there are two lines apiece of pinto and great northern beans. This year, at least two more green processing lines and three more of pintos are due out.

Many of the new lines boast more than rust resistance. Seven can resist or tolerate root rot that threatens beans in Florida, according to Robert T. McMillan of the University of Florida. And Matt J. Silbernagel of the ARS Vegetable and Forage Crops Production Research Laboratory, Prosser, Washington, verified that most of the lines resist most North American strains of bean common mosaic virus, the crop's worst virus disease.

Many rust-resistant lines began as primitive beans that USDA plant explorers have collected since the 1940's in Guatemala and other Latin American countries. Collecting and preserving germplasm—the genetic instructions in seeds and plant tissue—now pays big dividends.

"Several years ago," says Stavely, "we found that many strains of wild and cultivated beans resist one to as many as a dozen races. A few resist most of the 55 races. So at first we bred plants that combined resistance

J. RENNIE STAVELY

Alternating rows of susceptible and rust-resistant beans. (K-4394-20)

borrowed from several of these strains. The final product has resisted all 55."

To breed such beans, the scientists start by crossing a resistant strain with a commercial variety. In a greenhouse, they challenge each of the progeny of these crosses with at least eight races of rust. Then—at least three times—they backcross fully resistant plants to the commercial variety and retest the progeny. Next, in outdoor plots in bean production areas, the program's cooperating scientists test lines whose resistance is uniformly and reliably inherited.

The cooperators release the best lines to commercial and public breeders. These breeders work further with these lines to ensure that they have desirable yield, tenderness, flavor, seed and pod color and size, and other traits important to quality.

To complete the test cycle, many breeders then send these advanced lines back to the bean rust nurseries, where Stavely or other cooperators evaluate their rust resistance and other traits. This final evaluation helps the commercial and public breeders decide whether to release the beans as a new, rust-resistant commercial cultivar.

Since 1980, project technician Gene Frazier has made nearly 3,000 different bean crosses for the program in Beltsville. And the results have made Frazier and Stavely justifiably proud of the rust-free lines in their Beltsville bean plots—even though many other plants look, well, rusty to a casual visitor by late summer. By this time, one or more of five races of the disease take their toll of plants that didn't inherit the special genes.

SCOTT BAUER

Bean leaf at right is from a plant that can fight off most rust fungi. (K-4392-18)

"We only test five races here," Stavely says, "because they already occur naturally in our area. That way we don't risk introducing a new race. We test the other 50 races in the greenhouse in the winter and at other locations where they're already present."

By September, in several rows surrounding the nursery's hundreds of 3- or 6-foot-long mini-plots, thousands of bean plants lie mostly dead, brown, and leafless. These plants—of strains highly susceptible to rust—serve as hosts for rust spores that summer winds spread over the test plants in the nursery.

Many of the test plants succumb. But others stay green and lush, like a rust-resistant Slenderette—a popular green snap bean—that debuted in supermarket frozen-food cases this winter.

Stavely and Joseph Steinke of Rutgers University released these beans to breeders in 1986. Lynn Kerr of Idaho—and other commercial breeders—liked them.

Kerr, after further work to strengthen the beans' commercial qualities, sent them to Stavely for evaluation in the rust nurseries.

A bean producer—Seabrook Brothers and Sons of Seabrook, New Jersey—decided to try the super-rust-resistant Slenderettes on a small scale. Each year, Seabrook processes about 30 million pounds of green snap beans for the frozen-food market. Last fall's Seabrook harvest included about 200 acres of rust-resistant Slenderette grown from seed obtained from Kerr.

Seabrook contracts with about 60 farmers who grow the beans the company processes. Hank Wakai, a contract field man for Seabrook, says the rust-resistant Slenderette acreage was scattered among several New Jersey farms.

Rust epidemics struck the state in 1970-74, 1978-79, and 1983-84, and "that's why we need rust resistance," says Wakai. "Fortunately, it wasn't a problem last summer."

The rust-resistant Slenderette yielded as well as regular Slenderette, he notes. "We'll probably grow a larger acreage of the rust-resistant beans next year, and we may gradually switch over completely," Wakai says.

Stavely and Steinke made Slenderette rust resistant by first crossing it with B-190, a line bred and released in the early 1980's by ARS plant geneticist George Freytag in Puerto Rico.

"B-190 was one of the granddaddies of rust resistance. It's susceptible to only 8 of the 55 races," says Stavely, "and the beans we're working with now are even better sources of resistance."

If new rust races appear, he's confident that these beans—including ancient wild strains from Latin America—can again be called on to rescue modern-day growers.—By **Jim De Quattro,** ARS.

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Beans on the Research Menu

Beans are native to Central and South America, but the United States is the world's leading exporter, with a record 1.3 billion pounds of dry beans exported in 1990. Per capita, Americans that year ate 7.4 pounds of beans purchased dry—such as great northern, pinto, and navy beans—along with 3.7 pounds of frozen beans and 1.9 pounds of canned beans. No one knows how many pounds of fresh snap beans Americans eat, including those plucked from the backyard plot.

"If beans are on the menu," says ARS researcher J. Rennie Stavely, "the odds are USDA helped put them there. About 95 percent of the dry and snap beans grown in this country have some kind of USDA background in their genetic pedigree. Most also have traits put in by university and state breeders."

Major goals and locations of ARS research on the common bean, *Phaseolus vulgaris* include:

• Breeding lines of dry and snap beans resistant to rust (Beltsville, Maryland, and cooperating universities) and with combined resistance to viruses, root rots, and climatic stresses (Prosser, Washington).

• Dry bean germplasm and improved means of preserving it (Pullman, Washington).

• Technologies for preserving seeds and pollen of snap beans (Fort Collins, Colorado).

• Snap bean breeding lines and cultivars to resist root rot, blight, and root knot nematode (Charleston, South Carolina).

• Dry bean germplasm for the Tropics with multiple disease resistance, resistance to environmental stresses, and high yield (Mayaguez, Puerto Rico).

• Farming systems to maximize profits from snap beans and other vegetables grown on small farms (Lane, Oklahoma).

• Increased nutrient availability in dry beans (Ithaca, New York; East Lansing, Michigan).

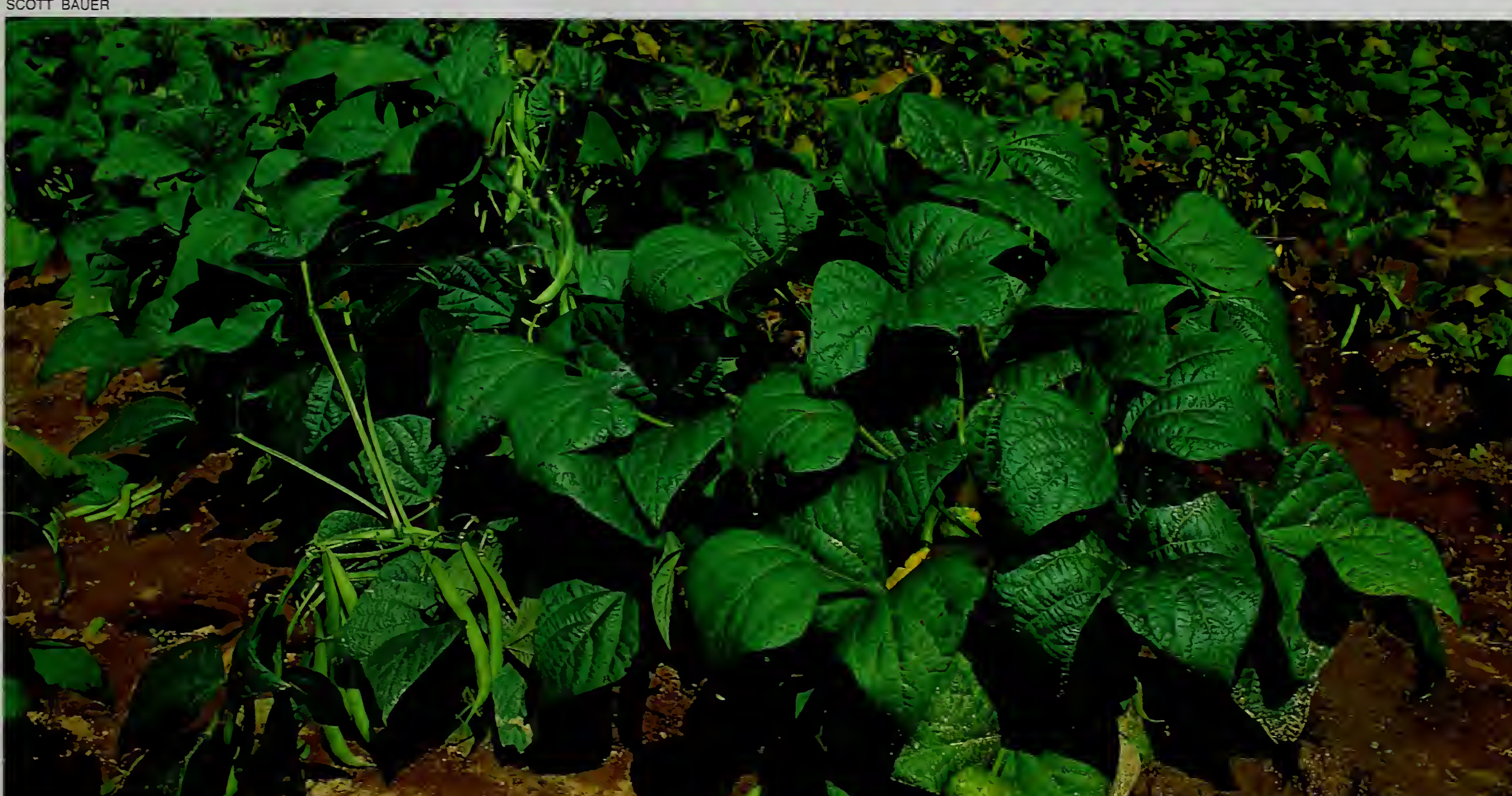
• Beneficial microorganisms as natural controls for soilborne diseases and rust in snap beans (Beltsville, Maryland).

• Controls for dry bean blight (East Lansing, Michigan).

• Reduced bacterial damage to snap beans by determining dynamics of bacterial growth on leaves (Madison, Wisconsin).

• New controls for insect pests of snap beans through combining feeding attractants, feeding stimulants, and killing agents (Lane, Oklahoma).

SCOTT BAUER



Resistant snap beans remain healthy after exposure to rust fungi. (K-4394-9)

Rain, Runoff, and Underground Water

When farmers aren't praying for rain they're praying for a way to save it.

Just an inch of rain on a 1-acre field amounts to 27,152 gallons. After a month's accumulation of 4 inches of rain, a farmer might find 1 or more of those inches have run off the field.

And with that water goes precious topsoil and costly pesticides and fertilizers. The topsoil and chemicals that reach streams, rivers, and lakes become contaminants.

If farmers wish to keep surface flow and erosion to a minimum they might switch to no-till, an energy-saving method of planting without prior plowing. This leaves previous crop residue on the surface to protect the soil. The residue slows the movement of water across the field, giving it time to soak into the soil.

Farmers planted crops with no-till on about 17 million acres of U.S. cropland last year and used reduced tillage on another 56 million acres. That's a quarter of the cropland with conservation tillage.

But critics point out that no-till farmers have more water going down toward groundwater, shifting the pollution threat from streams to aquifers. What's more, they say, no-till usually requires increased herbicide use to kill weeds that would have been uprooted by plowing.

Are these problems real and, if so, how do we deal with them? A long-term experiment on 1-acre corn plots in Beltsville, Maryland, is delivering some answers.

Agricultural Research Service scientists are already in their sixth year of building what plant physiologist Allan R. Isensee considers "one of the most complete data sets in the country."

Isensee, with the ARS Pesticide Degradation Laboratory, says he and soil scientist Ali Sadeghi are measuring just about everything involved in the movement of water carrying atrazine, alachlor, and cyanazine herbicides across and under cornfields.

The rain that falls on the fields is measured. The water evaporating from the fields is accounted for. The soil is sampled at 4-inch increments,

SCOTT BAUER

Soil scientist Ali Sadeghi (right) and plant physiologist Allan Isensee take samples from a shallow well for pesticide analysis. (K-4516-14)

down to 20 inches, to see how far the chemicals are moving down with the water. The groundwater is sampled from 128 wells drilled to depths ranging from 5 to 36 feet.

And rainwater that runs off the field is channeled through stainless steel flumes where ultrasonic sensors measure its level. Flowmeters connected to the ultrasonic sensors electronically convert the readings into flow rates and volumes. The meters also trigger automatic water sampling for every 75 or 100 gallons of flow. Back at the lab, the samples are analyzed for herbicide content.

SCOTT BAUER

Plant physiologist Allan Isensee and technicians Valerie McPhatter (center) and Juanita Yates (right) collect soil samples from a cornfield for further analysis. (K-4518-6)

As Isensee shows a visitor the fields, he notes some welcome news for farmers. With both no-till and conventional tillage, he hasn't found pesticides in the deepest wells, where groundwater might be used for drinking water.

As for the soil, with no-till there is less chemical residue in the first 4 inches than with conventional tillage.

But in the next 8 inches, the situation reverses—higher residues of herbicides with no-till. The good news is that there isn't much getting past the 1-foot mark, says Isensee.

And the chemicals that are in the wells are usually well below health advisory levels issued by the Environmental Protection Agency for drinking water. When levels approach or exceed these amounts, within 2 or 3 days they drop back as the aquifer dilutes them.

"No-till is here to stay," Isensee says, "so we have to learn how to take advantage of it and minimize any harmful side-effects. It does a great job of stopping soil erosion and the movement of chemicals attached to soil. We have very little slope here but we still see a substantial amount of soil eroding on the conventional plots and almost none on the no-till plots. It's saving farmers soil as well as fuel and time."

He says that on the Beltsville plots, no-till cut runoff from low-intensity storms (about an inch of rain) by at least half. However, on more intense storms, preliminary observations indicate that soil wetness before a storm affects runoff and pesticide loss more than tillage practice.

Isensee says that the conditions at Beltsville are generally similar to those in the midwestern Corn Belt. "The herbicides, the amounts, the silt-loam soil, and the rainfall pattern are all similar," Isensee says. "If anything, the conditions in the Midwest, with slightly less rainfall, are even less conducive to leaching than in the East." Leaching is the carrying downward of chemicals by irrigation or rainwater.

"We couldn't afford this intensive instrumentation in every part of the country," he says, "but if we can refine existing leaching computer models to account for regional differences, we could make accurate predictions of chemical movement for each major crop growing area in the country.

"Our long-term field database will provide modelers the opportunity for testing, validation, and perhaps improvement of existing models."

A comprehensive comparison of field observations and model predictions is the final step in verifying any model's worth, Isensee explains.

Of course, he notes, the real test of any model will be whether it helps farmers find conditions under which no-till needs fine-tuning to protect groundwater quality. And will it help them choose solutions such as applying encapsulated pesticides or applying pesticides only in narrow bands to restrict pesticide-soil contact as much as possible?

As a preliminary accuracy check, Sadeghi recently fed 2 years worth of data into an Environmental Protection Agency computer model. He points out that the predictions of pesticide residue amounts in the first 4 inches of topsoil came very close to those observed in the cornfields. However, because of model limitations, the predictions of pesticide residue below 4 inches were not comparable with field observations.

"We need models that can account for localized shortcuts for the transport of pesticides dissolved in rainwater or snowmelt," Isensee says. "These shortcuts might be root channels, soil cracks, and worm holes. They can cause a great increase in pesticide residues at greater depths in one small part of a field. This 'hot spot' condition is missed by models that compute averages for entire fields."—By **Don Comis,** ARS.

Allan R. Isensee and Ali M. Sadeghi are at the USDA-ARS Pesticide Degradation Laboratory, Beltsville Agricultural Research Center, 10300 Baltimore Ave., Beltsville, MD 20705-2350. Phone (301) 504-5533. ◆

When Is an Orange Not an Orange?

RANDALL SMITH

Cold-hardy Ambersweet oranges. (K-4391-1)

It's an orange! It's a tangerine! It's a grapefruit! Well, actually, it's all three.

"It's one-half orange, three-eighths tangerine, and one-eighth grapefruit," says plant breeder C. Jack Hearn.

Ambersweet, the newest orange hybrid developed by ARS horticulturist Hearn in the 1960's and released to growers in 1989, has been classified by the Florida Citrus Commission as an orange.

"This was for the purpose of fresh fruit sales," says chemist Manuel G. Moshonas. But about 90 percent of Florida's orange crop, he says, goes for processing into fresh and frozen orange juice.

Although Ambersweet looks, tastes, and smells like an orange, the U.S. Food and Drug Administration must decide how it should be classified on labels of processed juice products. Because it's a hybrid, current regulations would limit its use to 10 percent or less if the product is to be labeled orange juice.

"Right now, sweet orange, *Citrus sinensis,* is the only species that can be used without limitation in orange juice under FDA standards," Moshonas explains.

Moshonas has developed data to give FDA a scientific basis for its critical review, which will determine whether or not Ambersweet is classified as a juice orange.

Since Ambersweet is not currently considered part of the *C. sinensis* species, FDA analysts would need concrete data before agreeing to review their regulations on orange juice.

So at the ARS Citrus and Subtropical Products Laboratory in Winter Haven, Florida, Moshonas and fellow chemist Philip E. Shaw set to work. They needed objective evidence that would prove this new orange hybrid to have more characteristics of its orange lineage than of the grapefruit or tangerine.

With the help of Robert D. Carter from the Florida Department of Citrus, Moshonas and Shaw analyzed Ambersweet flavor and aroma constituents.

"We analyzed not just the juice, but oil from the juice and peel," Moshonas says, "and compared them with similar constituents from orange, tangerine, and grapefruit."

All 21 components identified in fresh orange juice were identical to those in Ambersweet juice. The same held true for oils.

"We did analogous comparisons with tangerine, Orlando tangelo, and grapefruit. Major differences in juice and oils, both qualitative and quantitative, were apparent," says Moshonas.

When he and Shaw used mass spectrometry and gas chromatography, even these highly sensitive computerized instruments were unable to differentiate juice of freshly squeezed Valencia oranges from Ambersweet juice.

"However, the equipment registered differences between Ambersweet and tangerine, Orlando tangelo, and grapefruit," Moshonas says.

Appearance Is Also Important

"To consumers, flavor and color are the most important characteristics of orange juice," says Shaw. Processors now must often blend juices from late-maturing orange varieties, imported orange juices, or small amounts of hybrid juices with juice from early-season varieties to meet USDA grade standards for color. For example, Hamlin—the major early-season variety—produces a very pale, weak-looking juice.

This blending process can be burdensome and expensive. Frozen concentrate has to be stored from the previous season for blending with Hamlin and Valencia juice. The costs are passed on to consumers in the form of higher prices for orange juice.

Processors imported about $641 million worth of orange juice in 1990, most of which was mixed with orange juice produced in the United States that didn't meet color standards.

But Ambersweet juice can stand on its own. In fact, because it exceeds the minimum color standards, it can be mixed with other orange juices that don't meet the government color requirements.

Bobby F. McKown is the executive vice president of Florida Citrus Mutual, which represents 12,300 citrus growers.

Gas chromatograph charts show how closely juice volatiles from Ambersweet resemble sweet orange's but differ from those of a tangerine.

"Our members strongly support Ambersweet as an orange not just because of its juice color, but primarily because it's cold hardy and matures early," he says. [See *Agricultural Research,* July 1990, pp. 13-15.] "We sometimes call it a designated hitter because it can serve both fresh and processing markets. Several varieties are well suited for one or the other, but Ambersweet is an excellent variety that suits both."

Ambersweet, which could stand alone or be blended with Hamlin, could make the processing industry less dependent on imports.

Process Protects Consumers

According to Martin Stutsman of FDA's Division of Regulatory Guidance, FDA is evaluating the May 1991 citizen's petition filed by the citrus industry that was based on Moshonas and Shaw's work.

"We have 180 days to either approve or deny the petition or make an interim response," he says.

If FDA agrees with the petition to modify existing standards of identity for various orange juice products, it would have to publish a proposal in the *Federal Register,* allowing an appropriate period for public comment.

If there are any objections to the proposed change, FDA must evaluate and consider them before publishing a final order.

"We are reviewing the Ambersweet petition but have not yet made a decision about publishing it as a proposal," Stutsman continues.

This regulatory process is designed to protect consumers by ensuring that competing products labeled with a common name meet common standards of identity.

FDA's decision is important also to citrus growers, some of whom have already planted substantial acreages to Ambersweet.

According to Roland L. Dilley, "We're talking about $200,000 worth of Ambersweet trees from our nursery alone that growers want to plant if they

RANDALL SMITH

Plant breeder Jack Hearn shows Ambersweet's easy peeling quality. (K-4391-5)

can use the fruit for processing." Dilley is president of one of Florida's largest nurseries, Roland L. Dilley & Son, located in Avon Park.

More than 200 Florida citrus nurseries are planting Ambersweet trees for marketing, with a few nurseries producing only Ambersweet.

More Like Fresh-Squeezed

Providing a scientific basis to classify a new orange variety is but one way the ARS Winter Haven lab is working to enhance the marketing of domestically grown citrus, for the benefit of consumers and growers alike.

"We've come up with a way to help processed orange juice taste more like fresh squeezed," Philip Shaw says. "Because of heat during pasteurization, it's almost impossible for processors to keep the delicate flavor of fresh-squeezed orange juice."

Again using gas chromatography, he and Moshonas accurately defined the mix of flavor components in fresh orange juice and the balance of the same compounds in commercially processed juices.

Natural flavor compounds are separated out of orange juice concentrate then added back in another stage of processing. Until now, according to Shaw, there had been no mechanism to identify and maintain the proper flavor balance.

Moshonas and Shaw are continuing their flavor research with aseptically packaged juice. They've found a way to retard flavor deterioration and add shelf life at the same time.

Packaged orange juice gets some of its flavor from orange peel oil and some from orange essence, both of which are added currently by the processing industry. However, peel oil can deteriorate at room temperatures, causing an off-flavor, Moshonas says.

To get around this problem, Moshonas and Shaw tried substituting concentrated orange essence in the process.

In the early stages of processing, a water distillate is collected that contains various flavor volatiles and other compounds. This is orange essence. It contains very little limonene, which tends to impart a bitter flavor.

Moshonas says that after the concentrated orange essence is added back to the product near the end of the processing, it markedly increases aroma and fruity flavor in the final juice product.

"An experienced 12-member flavor taste panel preferred juice flavored with our concentrated essence over juice flavored with peel oils," he says.

After all, taste is important and it's a key to nutrient quality. Last year, Shaw did a study that proved that if your morning 6-ounce serving of orange juice tastes good, then it probably contains enough vitamin C to meet the U.S. Recommended Daily Allowance.

"That study showed that in orange juice, flavor loss parallels vitamin C loss," Shaw reports.—By **Doris Stanley,** ARS.

Manuel G. Moshonas and Philip E. Shaw are at the USDA-ARS Citrus and Subtropical Products Research Laboratory, P.O. Box 1909, Winter Haven, FL 33880. Phone (813) 293-4133. ◆

Overcoming Greenbugs in Wheat

In the spring, when green winter wheat covers wide expanses of the Southern Great Plains, patches of yellowing and dead plants are a frustrating sight for farmers. The plants may be infested with greenbugs—aphids that inject a toxin into seedlings as they feed and inflict a $67 million loss on U.S. wheat farmers in an average year.

In most decades, however, there is a year or two that is far from average. In Oklahoma alone, damage and control costs in 1976 added up to some $80 million, about $150 million in 1991 dollars.

Greenbugs have a great capacity to hybridize, forming new races, or biotypes. When populations of major biotypes in nature are suppressed by insecticides or host plant resistance, new biotypes may begin to predominate, increasing their numbers rapidly through birth from unmated females.

ARS and Oklahoma State University (OSU) scientists, intent on preventing wheat losses as new biotypes appear, have reason for hope.

Five new breeding lines of wheat derived from lines developed in the 1980's by the late Emil E. Sebesta, ARS geneticist, are now known to resist the three most prevalent and destructive biotypes of greenbug—B, C, and E, plus a new and particularly devastating biotype, G. These wheat breeding lines are the first known to resist G.

"Our discovery of germplasm with multibiotype resistance should simplify efforts to develop new cultivars," says David R. Porter, an ARS geneticist at Stillwater, Oklahoma. Earlier efforts involved sequentially crossing several breeding lines to combine the desired resistance genes.

Greenbug resistance in the new lines is believed to have come from a rye chromosome in a wheat/rye hybrid that Sebesta treated with x-rays before making a series of further crosses with wheat. [See *Agricultural Research,* September 1991, pp. 22-23.]—By **Ben Hardin**, ARS.

David R. Porter is at the USDA-ARS Plant Science Research Laboratory, 1301 N. Western St., Stillwater, OK 74075. Phone (405) 624-4212. ◆

JACK DYKINGA

Greenbugs on a wheat leaf (magnified about 15 times). (K-4480-12)

JACK DYKINGA

Geneticist David Porter and technician Rita Veal examine a new wheat strain that is more resistant to greenbugs. (K-4480-13)

Checking Honey Bee Productivity

A sensitive electronic scale that automatically weighs bee hives every 15 minutes day and night is giving scientists in Tucson, Arizona, a better understanding of the hard-working honey bee.

Readings from the scale indirectly measure such things as number of insects foraging at different times of the day and when the bees brought back the most nectar and pollen.

Rapid weight loss of a hive can mean pesticides have killed foraging bees or that the queen is dead. The sooner a beekeeper learns of these conditions, the sooner the hive can be brought back to health.

Consistent gains indicate bees are doing their job—collecting nectar for honey production and more importantly for U.S. agriculture, pollinating up to $10 billion worth of crops annually.

Agricultural Research Service entomologist Stephen L. Buchmann has recorded hive weight changes for 2 years in the Sonoran Desert near the Carl Hayden Bee Research Center in Tucson.

This is the first time an electronic scale—accurate to within 0.035 ounces—has been connected to a personal computer programmed to take readings every 15 minutes. Previously, researchers and beekeepers had to move the 150-pound hives onto a portable scale and manually record hive weights. Because of the required labor and time, hives were weighed weekly.

"We can tell how many bees are in the hive by analyzing changes in the hive's weight. For example, if we didn't know how many 10-pound bricks were in a wrapped box, we could put the unopened box on a scale. If it weighed 50 pounds, we'd know there were 5 bricks inside. Our technique is similar except it's far more sensitive. We can detect the departure of as few as 8 to 10 foraging bees from a hive," says Buchmann.

"So far, our most interesting discovery with the electronic hive has been the speed with which foraging worker bees recruit others to visit the most productive plants," says Buchmann.

"Bees are very efficient social insects. They communicate with dances and wing sounds to tell one another about the best pollen source within a 30-square-mile area.

"We used to think it took them 2 to 3 days to shift to a better pollen source. Our electronic hive showed us they can communicate and recruit most of the hive in about a day and sometimes in just 1 hour."—By **Dennis Senft**, ARS.

Stephen L. Buchmann is at the USDA-ARS Carl Hayden Bee Research Laboratory, 2000 East Allen Rd., Tucson, AZ 85719. Phone (602) 670-6380. ◆

Intensifying Tomato's Flavor

Your favorite spaghetti sauce or tomato soup might taste even better with a new seasoning cooked up by ARS researchers. The scientists developed the blend while researching ways to improve the flavor of fresh tomatoes. Their product, a patented blend of tomatoes' best natural flavors, enhances the rich taste of foods made from tomato paste or sauce.

It can also add the flavor of cooked tomatoes to foods like corn chips or hamburger that normally don't contain tomatoes.

In taste tests, flavor panelists said a high-quality spaghetti sauce and a popular tomato soup had an even better aroma when seasoned with the blend.

ARS research chemist Ronald G. Buttery and colleagues at the ARS Western Regional Research Center, Albany, California, produced the flavor mix. Surprisingly, none of the individual tomato compounds in their formula have the aroma or flavor of cooked tomatoes, he says. Instead, it's the combination of the natural chemicals, and the proportion of each, that create the pleasing fragrance and taste.

Buttery is an authority on tomato flavor. In experiments, he and co-researchers identified—from hundreds of flavor-imparting chemicals in tomatoes—those most important to tomato paste aroma.

They also calculated the natural ratio of each compound. These chemicals had the highest aroma ratings, that is, a score based on data from an instrument (gas chromatograph) and on the perceptions of sensory analysts who sniffed tomatoes' aromatic chemicals.

JACK DYKINGA

Technician Louisa Ling prepares tomato paste sample for flavor analysis by chemist Ron Buttery at the Western Regional Research Center. (K-4507-1)

The researchers then chose seven of the highest ranking of these aroma compounds for the flavor blend. They used most of the chemicals in about the same proportion that they occur naturally in cooked tomatoes.

Most of the compounds are available from commercial sources, and all but one are already approved for food use.

Buttery says the blend can be encapsulated in gelatin to sprinkle on foods and can also be mixed with salt, black pepper, garlic powder, dried herbs, or other familiar seasonings.

One drop, says Buttery, is "enough to boost the flavor of 20 one-quart jars of spaghetti sauce."—By **Marcia Wood,** ARS.

For further information on Patent No. 5,064,673, "Cooked Tomato Flavor Composition," contact Ronald G. Buttery, USDA-ARS Western Regional Research Center, Cereal Product Utilization Research, 800 Buchanan St., Albany, CA 94710. Phone (510) 559-5667. ◆

Barnyard Flies Don't Make Good Neighbors

Nuisance flies from dairy farms can cause friction between farmer and suburban city folk. As the subdivisions move into farming areas, new methods of controlling these troublesome insects have to be developed.

"House flies can also hurt farmers because milk inspectors will not grant 'Grade A' milk status to farms with too many flies," says ARS animal scientist Richard W. Miller.

Unfortunately, flies have become resistant to most currently used insecticides. And it is becoming more difficult and expensive for companies to develop and register new ones with the U.S. Environmental Protection Agency.

To help solve this problem, ARS' Livestock Insects Laboratory in Beltsville, Maryland, and Cornell University's Veterinary Entomology Program in Ithaca, New York, began a cooperative venture on agricultural fly suppression in 1986.

"We needed an environmentally safe, practical, affordable fly-control system for farmers. We chose a combination of parasitic wasps, good sanitation, and a safe insecticide to combat the flies. In other words, integrated pest management, or IPM," says Miller.

"House flies on dairy farms were reduced up to 65 percent under the 3-year pilot test program conducted in Maryland and New York."

Four farms were treated in Maryland plus three in New York. Additionally, three other farms in each state served as controls for comparative purposes.

Available commercially, *Muscidifurax raptor* is a parasitic wasp that preys on flies. It lays its egg in the fly pupa. The newly hatched wasp feeds on the developing fly within. After the adult wasps emerge from the dead fly pupae, they mate and find other fly pupae to lay their eggs in, repeating the cycle.

Between 20,000 and 25,000 wasp-parasitized house fly pupae were released per farm per week in fly breeding areas. "Releases were made once a week because the flies breed so fast, they would soon outbreed the wasps," says Donald A. Rutz of Cornell University. Releases were started early in the summer so that the flies wouldn't get a head start on the wasps.

Since many flies develop in calf bedding during the summer, cleaning out the pens once a week was an important component of the tests.

Pyrethrin, an environmentally safe insecticide, was used infrequently as a space spray—when the farmers thought the flies were getting ahead of the other control methods.

"Insecticide use on the IPM farms was reduced by 80 percent compared with those that were conventionally managed. In spite of reduced insecticide use, fly populations on the IPM farms were less than half those on conventionally managed farms," says entomologist Christopher J. Geden, also of Cornell.—By **Vince Mazzola,** ARS.

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Extending the Forage Season

A weed that farmers and ranchers curse has proved to be a surprising ally for scientists working to breed better forage grasses.

By uncovering a secret to the weed's success, they're making progress on new forages that could thrive under the cool temperatures of early spring and late fall.

That could extend the grazing season, lessening ranchers' reliance on harvested hay. Feeding hay to livestock during the winter costs more than allowing the animals to graze, says plant physiologist N. Jerry Chatterton.

Chatterton and colleagues at the ARS Forage and Range Research Laboratory have shown that *Bromus tectorum*, an aggressive weed commonly known as cheatgrass, relies on special carbohydrates called fructans to help the plant grow.

"That's one reason why cheatgrass often out-competes desirable range plants," explains Chatterton, who is research leader at the Logan, Utah, based lab.

"It sprouts early in the fall, stays green during the winter, and puts on new growth earlier in the spring because it is able to use fructan as an alternative energy source," he says.

Fructans are made of chains of primarily fructose molecules—the same sugar that gives fruits their sweet taste. Other so-called cool-season plants—those that grow well under cool temperatures—include forages such as wheatgrasses, timothy, and orchardgrass.

Chatterton identified 10 unique fructans in cheatgrass. To do that, he first had to develop methods to analyze the carbohydrates, as well as purify and identify standards for the different fructans. Although standards already exist for other carbohydrates—starches (polymers made with glucose), for example—the structures of grass fructans had never been characterized.

He and colleagues hope to identify and eventually clone the genes that enable cheatgrass and other cool-season grasses to make fructans. Those genes cue plants to produce enzymes needed to convert fructans into energy for growth. "Through genetic engineering, those genes could then be enhanced in cool-season plants or transferred to warm-season plants, like bermudagrass, bahia grass, or sorghum, to give them the ability to withstand cool temperatures," says Chatterton.

With the new genes, bermudagrass—a common lawn and forage variety—might stay green instead of turning brown over the winter. And, according to Chatterton, ranchers could save up to $1 per cow for each day their cattle eat grass instead of harvested hay.

That means using the new technology on forage grasses to extend the grazing season for just 2 weeks each year could save a rancher with 200 cattle as much as $2,800 per year.—By **Julie Corliss**, ARS.

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